SWEDISH CONIFEROUS FOREST PROJECT
BARRSKOGSLANDSKAPETS EKOLOGI

INTERNAL REPORT 63 1977

RESEARCH NOTES ON DECOMPOSITION 1-4

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ISSN 0346-7589
ISBN 91 7544 063-6

Contents

Abstract

Page

1. Studies on cellulose decomposition in pine stands of different age at Ivantjärnsheden, Jädraås, Sweden........... 4

2. Transport of pine needles through a moss comunity of the S-layer in a 120-year-old stand of *Pinus silvestris* (Ih VA, 2nd paper)... 15

3. Electron microscopic studies on decomposing needle litter from *Pinus silvestris* - a preliminary study................ 20

4. Wind transport of needle litter in a clear-cut area.........

RESEARCH NOTES ON DECOMPOSITION 1-4

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Abstract

1. Cellulose decomposition was studied in pine stands of two different ages and in a clear-felled area at Ivantjärnsheden with the aim of detecting differences in decomposition rates among the stands and in some transects. In one year, pure cellulose lost about 11% of its weight on the soil surface of the clear-felled area and in a 15-year-old stand whereas in a 120-year-old stand the weight loss was 18%. Decomposition rates increased with depth and in the mineral soil the weight loss rates in the different stands were about equal, with around 95% per year. Decomposition rates were studied in some selected transects.

2. Downward transport of needle litter through the S-layer moss has been determined for *Dicranum* sp. in Ih VA. Transport time through the layer is estimated and some methodological aspects mentioned.

3. Decomposition of needle litter was observed and followed by electron microscopy and some preliminary conclusions are drawn about decomposing microorganisms, *viz.* it appeared that fungi are the first decomposing microorganisms, penetrating into the cells.

4. In a clear-cut area wind transported needle litter on the ground - in summer more than 2 m per month.

1. STUDIES ON CELLULOSE DECOMPOSITION IN PINE STANDS OF DIFFERENT AGE AT IVANTJÄRNSHEDEN, JÄDRAÅS, SWEDEN

1. Introduction

Microbial activity is known to depend on different factors such as temperature, soil moisture and pH. Within relatively small areas, e.g. one square metre, different conditions exist which will affect microbial activity. A process, such as decomposition of a certain substrate, can have considerably different rates at different spots within such an area. At the site of the Swedish Coniferous Forest Project at Jädraås (Ivantjärnsheden) differences in soil moisture and temperature are easily found in the organic soil layers even within areas less than one square metre of a uniformly aged stand of *Pinus silvestris* - probably due to variations in the vegetation cover. When carrying out decomposition studies it is necessary to use a number of parallel samples large enough to register the variations and give representative test results for the site.

Changes in the vegetation cover, such as thinning or clear-felling will affect the microclimate to such an extent that large differences in decomposition rates are obtained. Piene (1973) reported that thinning of a spruce forest raised the decomposition rates of cellulose and spruce needles, probably due to changed microclimate.

Lähde (1974) studied decomposition rates in a birch and a pine forest located close to each other and with similar microclimate and found about double the decomposition rate in the birch forest. He also found a lower decomposition rate under a pine canopy as compared to outside its projection on the ground. This effect might have been due to other factors than microclimate.

The aim of the present study was to trace differences in decomposition rates within and between some of the stands at Ivantjärnsheden. The study is to be regarded as an investigation for detecting differences in decomposition rates in different environments. Studies on decomposition, organized to fit in a simulation model are being carried out and the present study will enlighten the explanation of the differing decomposition rates obtained in the sites.

2. Materials and methods

2.1 Areas of study

A 120-year-old stand, a 15-year-old stand of *Pinus silvestris*, and an area without vegetation –, clear-felled 5 years before the present study was started –, were investigated. Some studies were also carried out in a 55-year-old stand. The areas (Fig. 1), located on sandy sediment, are studied regarding climate (information from the meteorology group), soil properties (Pettersson 1975) and vegetation (Bråkenhielm 1974).

2.2 Cellulose

The cellulose used, a dried preparation in sheets (Borregaard) obtained from Borregaard A/S (Sarpsborg, Norway) consisted of 100% glucan and 0.4% ash. Each sheet, measuring 5x5 cm^2, weighed about 2 g.

2.3 Start of experiment

The cellulose samples were put out on 14 June, 1973 on 20 randomly selected spots in each stand and taken up after 365 or 469 days with 10-20 samples each time. The pieces of cellulose were not put into litter-bags but placed directly in the soil at different horizons. In the 120-year-old stand they were placed on the S-layer, between S- and litter-humus (FH-) layer and at 2 and 5 cm depth in the mineral soil. In the 15-year-old stand cellulose samples were placed on the ground and in the H-layer. On the clear-felled area, samples were placed on the ground, at the border of the H-layer and the mineral soil (A_1-horizon) and 2 and 5 cm down in the mineral soil. The pieces were always placed horizontally and on the surface they were kept in place by a hair-net which was tightly pegged down by metal pins.

2.4 Transects

Samples were placed in a transect over an anthill with samples (10 parallels) on its top, at its foot, and at distances of 0.5 m, 1 m and 4 m from it.

The decomposition in transects from *Pinus silvestris* canopy projections was studied by placing cellulose samples under and outside the canopy projection (15-year-old stand). The samples were placed in groups of 5 under and outside the projection, viz. 10 at each tree and level. In the 120-year-old stand samples were placed at distances of 0.1, 0.5, 1.0 m from the stem and outside the canopy projection (15 parallels).

When taken up, the samples were washed and sand particles removed. Weight loss was determined after drying at 105° for 5h. Remaining sand in the samples was corrected for after burning the samples in an oven at 700° and weighing the ash.

3. Results and discussion

3.1 Methodological aspects

The type of cellulose preparation used in the decomposition studies has earlier been found to be the most suitable of those available. Litterbags have earlier been found to influence the degradation rate (Rosswall & Berg 1973). The absence of litter-bags, however, caused other difficulties. The cellulose pieces were often fragmented, particles having loosened from their surfaces, especially in the 15-year-old stand and on the clear-felled area. In these stands the pieces of cellulose were exposed to wind and rain, the combined effect of which probably rugged the surface and loosened fibre-sized particles. In the 120-year-old stand no such effect could be seen. The pieces in the anthill were also fragmented but to a minor extent. These fragments were, however, somewhat larger, around 0.5 x 0.5 cm^2, and could have been caused by the ants. The use of hair-nets to keep the pieces of cellulose in place was not successful since they quickly became brittle and thus often disintegrated.

It appears that a certain level of decomposition must be reached before the differences in decomposition rates within a transect are large enough to be detected (Table 1). It could be expected that the weaker the effect of a transect on decomposition, the higher degree of decomposition would be needed to distinguish the effect and vice versa.

Variations in weight loss values among parallel samples will reflect differing conditions for decomposition within the test spot selected. A high value of standard deviation (SD) will thus indicate very differing conditions for decomposition. A low value, on the other hand, will reflect rather homogenous conditions for decomposition.

The different weight loss values among parallel samples are a consequence of different decomposition rates. Assuming a decomposition process roughly corresponding to the graph in Fig. 2 we would expect the greatest differences in weight loss and SD among parallel samples around 50% decomposition (Lindgren, pers. comm.). The calculation of SD only includes the absolute values,

$$SD = \frac{(x-\bar{x})^2}{n-1}$$

where: x is each one of n values
$\bar{x}$ is the mean of n values

that is; the sizes of the differences between the average value and the single weight loss values. As great differences among parallel samples thus give rise to high SD values, one clearly has to be careful when drawing conclusions about the meaning of SD as well as when comparing decomposition and variation in decomposition at different sites.

Different decomposition rates within a site might reflect an inhomogeneous site e.g. varying temperature, moisture, vegetation cover etc. and low values should thus indicate a rather homogeneous site.

When using SD as a measure to compare the homogenity of different sites it is necessary that values on the relation p (100-p), where p is weight loss in per cent, gives about the same numerical value for the weight loss values of the sites.

3.2 Differences in decomposition among the different stands

The decomposition rates on the surface of the clear-felled area and the 15-year-old stand were not significantly different but decomposition might be somewhat slower on the clear-felled area (Table 2). Decomposition rates of cellulose on the surface of the 120-year-old stand versus those of the clear-felled area and the 15-year-old stand were significantly different ($p<0.01$ and $p<0.02$ respectively). The slow decomposition on the clear-felled area could be due to its relative dryness since no moisture preserving lichens, mosses or dwarf shrubs were present. The area is very windy and completely exposed to sunlight since no vegetation gives shadow and evaporation thus is enhanced and the site relatively dry. The pines and the dense cover of *Calluna vulgaris* in the 120-year-old stand create relatively moist conditions as do also the mosses and lichens. The surface is comparatively little exposed to direct sunlight and there is very little wind at the surface which also favours lower evaporation (Perttu 1972). The differences in mean temperature and temperature amplitude further emphasize climatic differences between the stands (Perttu, pers. comm.).

In the 15-year-old stand the decomposition seemed to be somewhat higher than on the clear-felled area but the values were not significantly different. These two areas bordered each other and since the 15-year-old stand was comparatively small (about 50 m x 100 m) it is very probable that the climate was affected by - and similar to - that of the clear-felled area. The stand has no mosses and only a little lichens but the amount of pines (about 3-4 m in height) and the clones of *Calluna* reduced wind speed at the ground surface and reduced its exposure to direct sunlight.

Since the soil profiles in the stands are different it was difficult to carry out a satisfactory comparative study of decomposition. It can be seen, however, that the rate of decomposition increased with depth and could be due to more constant moisture levels in the FH-layer and mineral soil than on the surface. This observation appears to be valid for all three stands (Table 2). A comparison can also be made between the values for the middle of the FH-layer, where decomposition in the 120-year-old stand appeared to be twice that in the 15-year-old stand ($p<0.01$). In the clear-felled area the H-layer was very thin and brittle. It would thus be difficult to carry out a comparative study at a corresponding layer in this area.

At 2 cm depth in the mineral soil it seems - although decomposition was very high - that the rate was higher in the clear-felled area than in the 120-year-old stand ($p<0.20$).

3.3 Decomposition of cellulose in transects

3.3.1 Transects from tree canopies

It did not appear possible to relate position in transect to obtained differences in decomposition among cellulose samples placed in a transect from the stem of 120-year-old pine (Table 1). Differences were, however, found in two separate studies carried out in the 15-year-old stand (Table 1). The cellulose samples were placed in groups at different trees and from the results it seemed that there was a rather large variation in decomposition between the subsites. A t-test on all the values for decomposition (in one of the experiments) under the canopies and comparison of the results with those outside its projection, showed a difference of $p < 0.15$, whereas when determined at individual trees the values were $p < 0.4$. The second measurement was carried out a year later and indicated a higher decomposition outside the canopies than under them. There are a number of possible explanations. One reason could be that inhibitory substances present in the needles could influence decomposition rates. Lähde (1974) carried out a corresponding study and discussed this reason for the difference in rates. It is also possible that differences in moisture and temperature could have an influence.

Although the decomposition appeared higher outside the canopy projector than under it there seem to be other factors which have at least as large an influence, e.g. position south of a tree with exposure to the sun, as compared with a relatively shadowy position north of a tree. Shrubs clearly affected weight loss, and weight loss of cellulose was three times as high on the ground under heather than outside the clone.

In the 15-year-old stand the effect of canopy projection ought to be more stressed than in the 120-year-old stand. The canopies in the older stand have a diameter of about 5-6 m and are located at a height of 8-12 m which caused a less pronounced effect than in the 15-year-old stand, especially since the canopy cover is comparatively continuous. In the young stand the lowest branches of the canopies are located at 30-40 cm above the ground and the needles do not fall outside the canopy projection.

The differences in decomposition rates observed at the humus/mineral soil border in the 15-year-old stand did not appear to be significant (Table 1).

3.3.2 Transect from an anthill

Only few conclusions can be drawn from the decomposition values obtained. The degradation within the top of the anthill was 27% yr^{-1} whereas 0.5 m from the anthill 43% of the cellulose was degraded. The low value obtained at the top as compared with that 0.5 m from the anthill might be due to less moisture or possibly to a preserving effect caused, e.g. by formic acid.

3.3.3 Conclusions about cellulose as a substrate

Due to the high variation among parallel samples cellulose is difficult to work with. It is not to be recommended for studies of the kind presented here.

4. Literature

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Table 1. Percentage loss of initial weight of cellulose in transects from pine stems, standard deviations (SD) within brackets.

		365 days		469 days	
		Under canopy	Outside canopy	Under canopy	Outside canopy
15-year-old stand n=10	On surface of S-layer	10.5 (6.3)	11.9(5.4)	14.6(3.5)	23.8(9.8)
	Border humus/ mineral soil A_1	36.9(17.7)	32.6(9.2)	47.7(19.0)	51.5(7.0)

	Distance from stem			Outside canopy projection
	0.1 m	0.5 m	1.0 m	
120-year-old stand on surface n=15	9.1(3.9)	9.4(3.1)	12.4(6.2)	8.7(3.1)

Table 2. Percentage loss of initial weight of cellulose in 365 days in two pine stands of different age and a clear-felled area at Ivantjärnsheden, SD within brackets.

	Samples on randomly selected spots				
	On surface of S-layer	Between S- and FH-layer	Middle of FH-layer	A_1-horizon	Mineral soil 2 cm
Clear-felled area n=40	10.7(4.4)	-	-	90.5(21.5)	95.6(12.0)
15-year-old stand n=20	11.2 (5.8)	-	43.8(13.9)	-	-
120-year-old stand n=40	18.0(10.1)	60.9(26.5)	75.8(15.8)	-	92.3(15.2)

Measured variations (S.D.) within one square

Clear-felled area n=20	4.2
15-year-old stand n=20	11.9
120-year-old stand n=20	20.8

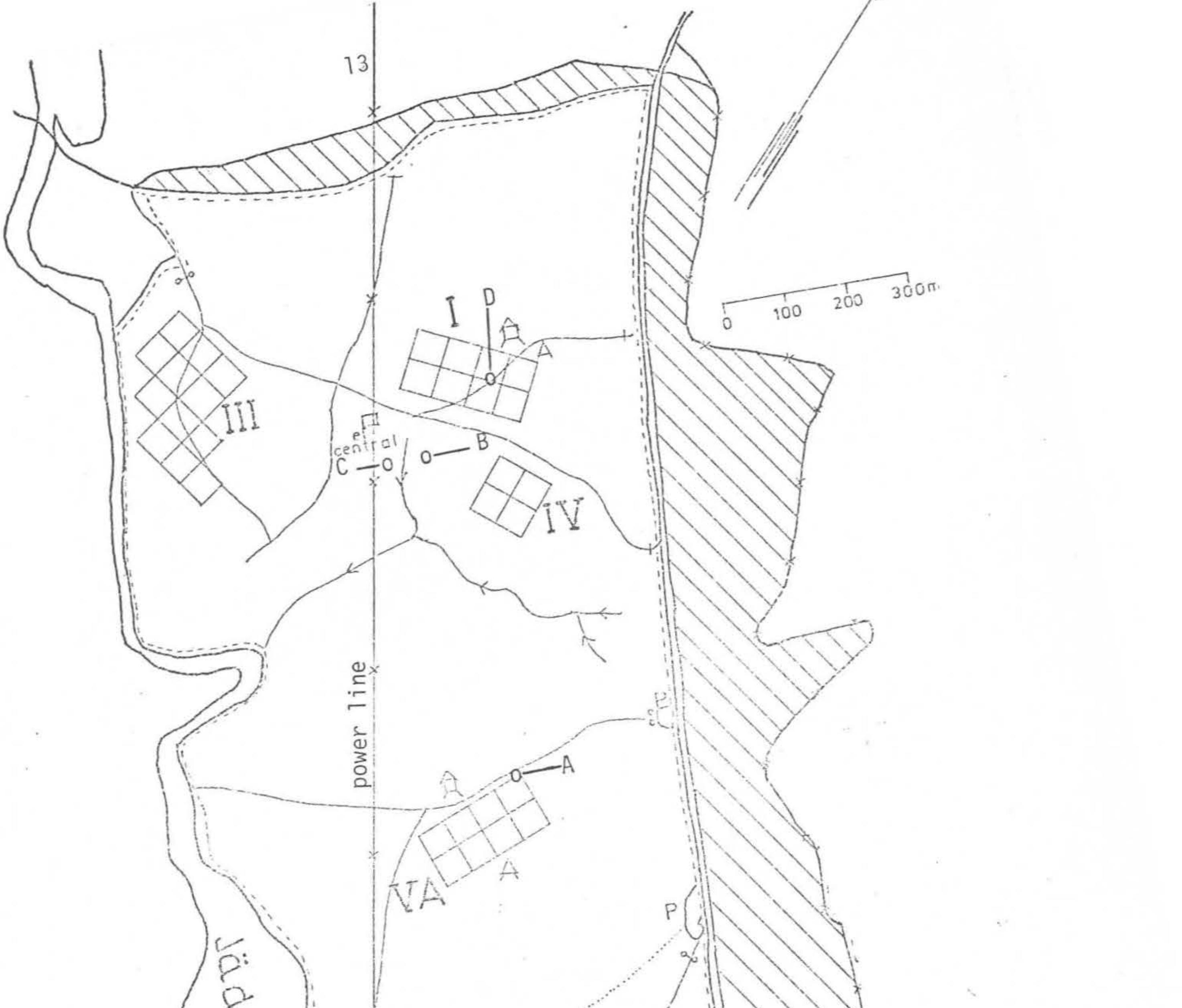

Fig. 1. A indicates the test spot in the 120-year-old stand (Ih VA).
B indicates the test spot in 55-year-old forest close to Ih IV.
C indicates the test spot in 15-year-old stand close to Ih IV and Ih I.
D indicates the test spot on the clear-felled area (Ih I).

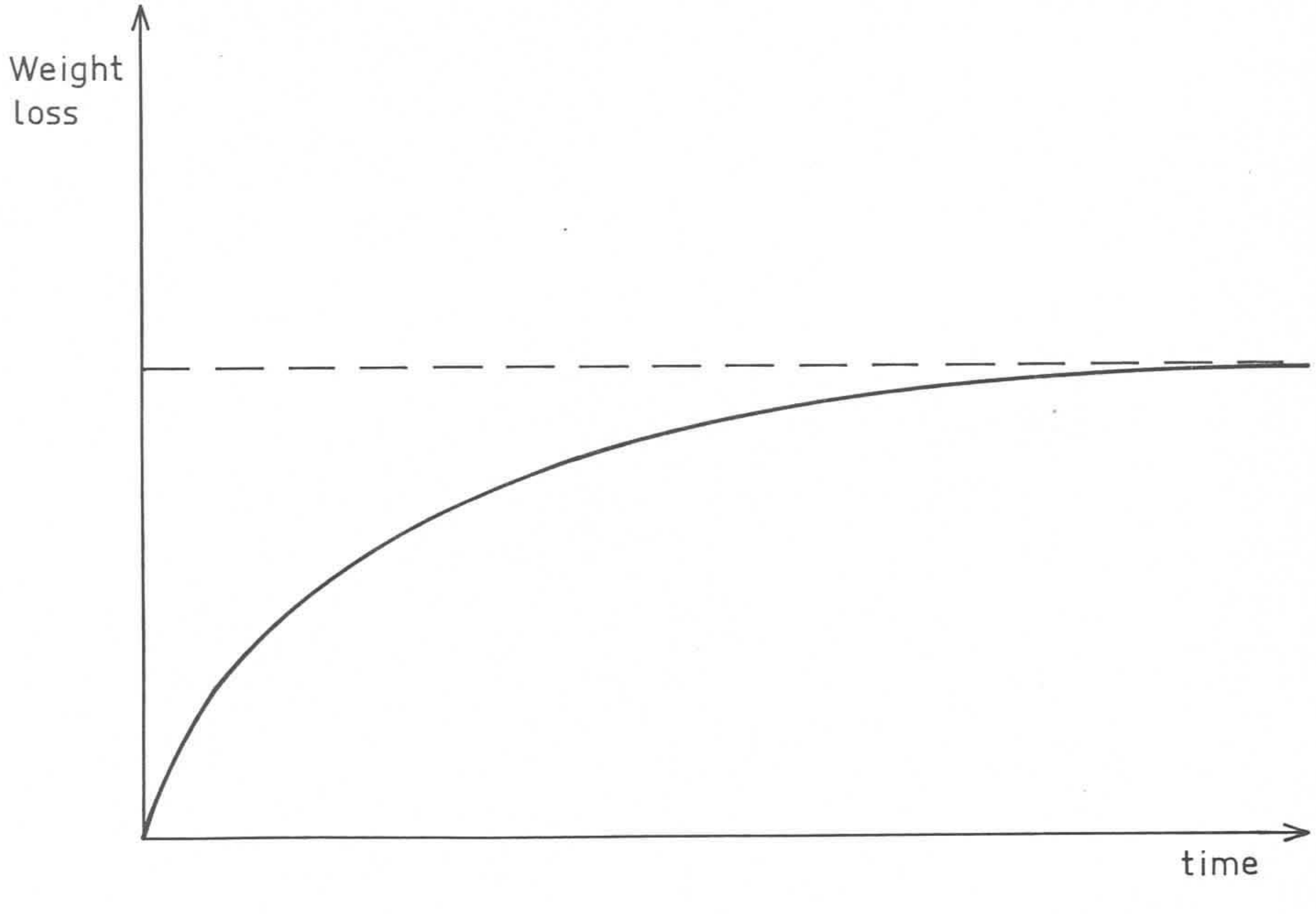

Fig. 2. Graph showing the kinetics of weight loss with time for litter.

2. TRANSPORT OF PINE NEEDLES THROUGH MOSS COMMUNITIES OF THE S-LAYER IN A 120-YEAR-OLD STAND OF *PINUS SILVESTRIS* (Ih VA)

1. Introduction

Microbial degradation of litter is dependent on factors such as temperature and moisture which are expected to change within even a short moss profile. The decomposition rate of litter could thus change gradually as it is transported downwards in the moss/lichen profile. The S-layer in the 120-year-old *Pinus* stand is dominated by the mosses *Pleurosium* and *Dicranum* and species of the lichen *Cladonia* (Bråkenhielm, 1974).

The transport of particles through the S-layer is likely to depend on the growth rate of the mosses/lichens. Particles of different size and form could be transported at different rates. Study of the transport of the different litter types is, however, time-consuming and it was therefore decided that needles - being the dominant litter fraction - should be studied. The present report is the last in this series and summarizes the results of two samplings, the first of which has already been published (Berg, 1975). These results will be used in connection with studies on decomposition rates in the S-layer.

2. Materials and methods

Needles were marked with a spot of white paint at one end and samples of 250 were spread over small areas (30 x 40 cm^2) covered with the moss *Pleurozium* or the lichen *Cladonia*.

The experiment was started on 23 May, 1973 and the first sampling was carried out on 10 June, 1974 (383 days) and the second one on 5 May, 1975 (712 days). A moss/lichen sample measuring about 15 x 15 cm was carefully taken up and moistened in the laboratory to soften it. Moss and lichens were carefully removed one by one with a pair of scissors and the position of the white spot on each needle was determined in relation to the lower part of the layer.

3. Results and discussion

About 10% of the marked needles were never recovered, possibly due to loss of the white marking. Approximately 50 needles were counted in each sample and the average position determined (Table 1).

It appears that the transport might be slightly faster through the lichen community, where the needles had reached the middle of the layer after one year. In the moss layer, however, most of the needles had only been transported down to the upper third of the layer. The reason for this might in part be due to the moss having a thicker texture than the lichen.

In the two-year sampling the needles in the moss carpet were transported down almost to the middle of the layer. Unfortunately the transport rate of the needles in the lichen was not directly comparable to that of the first sampling since the samples had very different thicknesses and no meaningful measurements could be carried out. The variation in position appeared to have increased between the samplings.

Any calculation of the time taken for the needles to pass through the layer will need certain assumptions, and the attempt made (Fig. 1) might be dubious. However, the extrapolated value fits fairly well with the estimated growth rate of the moss species at this site. According to Andersson (pers. comm.) the yearly growth could be a fifth of the moss' biomass. The lowest part of the living moss layer could thus be about five years old and the growth rate could be the main factor determining the downward transport of needle litter and probably other litters of similar or larger sizes.

The information obtained from this study does not enable a discussion of the transport rate down through the layer of attached dead moss. The purpose of the study was to obtain an estimate of the transport time.

The information now available appears to fulfill this aim and further discussions of the subject could refer to growth rates of the mosses. The term "transport" should possibly be reconsidered and where needle litter and other litters of similar size are concerning a better word might be "overgrowth".

4. Literature

BERG, B. 1974. Transport of pine needles through moss and lichen communities of the litter layer in a 120-year -old stand of *Pinus silvestris* (Ih VA). In: Swed. Conif. For. Proj., Int. Rep. 13, pp. 19-21. E. U. Granhall.

BRÅKENHIELM, S. 1974. Ivantjärnshedens vegetation (The vegetation of Ivantjärnsheden). Swed. Conif. For. Proj., Int. Rep. 18 (Uppsala), 51 pp.

Table 1. Transport of pine needles of 3-4 cm length down through the S-layer in a 120-year-old stand of *P. Silvestris* (Ih VA). Transport rate was measured in communities of the moss *Pleurozium* and the lichen *Cladonia*. With the assumption of even distribution of the needles within the spot the found loss was about 10%.

Position of needle measured from the bottom of the layer (cm)	Number of needles at different levels		
	First year sampling		Second year sampling
	Moss layer 7-8 cm thick	Lichen layer 6-7 cm thick	Moss layer 7-8 cm thick
8.0	0	-	1
7.5	0	-	0
7.0	4	0	1
6.5	0	0	4
6.0	21	0	3
5.5	13	0	6
5.0	0	2	5
4.5	0	7	8
4.0	4	8	7
3.5	0	4	7
3.0	9	9	5
2.5	0	5	2
2.0	0	4	0
1.5	0	3	0
1.0	0	2	0
0.5	0	0	0
0.0	0	0	0
Total number counted	51	44	49
Average position:			
from bottom	5.3	3.3	4.6
from top	2.6	3.7	3.4

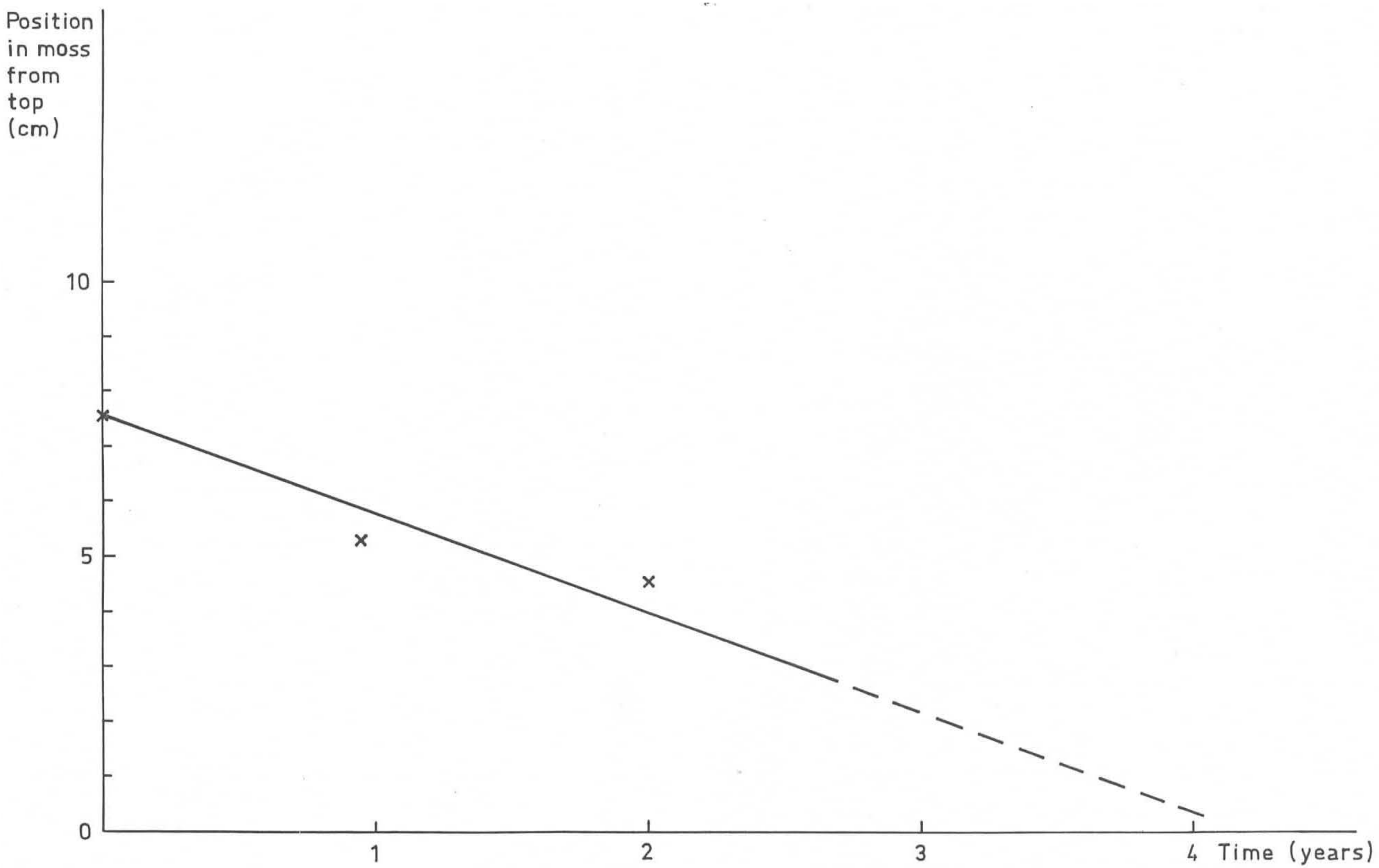

Figure 1. Downward transport of pine needles versus time

3. ELECTRON MICROSCOPIC STUDIES ON DECOMPOSING NEEDLE LITTER FROM *PINUS SILVESTRIS* - A PRELIMINARY STUDY

1. Introduction

In studies on decomposition processes much information can be obtained from microscopic and electron-microscopic investigations. It is possible for example to study mode of attack by or growth of the microorganisms (Nilsson 1974; Berg, v. Hofsten & Pettersson 1972). Under certain conditions it is possible to distinguish between and to draw conclusions about the roles of the different organisms seen in the electron microscope (v. Hofsten, Berg & Beskow 1972; Granhall & v. Hofsten 1976).

The aim of the present electron microscopic study was to describe the mode of attack by microorganisms on the pine needles as a complement to the quantitative decomposition studies.

2. Materials and methods

2.1 Litter sampling

Needle litter was sampled from the uppermost part of the moss layer and the middle of the moss layer in Ih VA in early May. The needles sampled in the uppermost layer were light brown with some dark stains on them and those from the middle of the layer were dark brown.

2.2 Electron microscopy

The litter samples were immediately pre-fixed in buffered 2.5% glutaraldehyde, pH 6.8, further fixed in 2% OsO_4 solution, suspended in 2% Difco Noble agar and dehydrated in an ethanol gradient before embedding in Epon (v. Hofsten & Holm 1968). The embedded material was sectioned on an LKB Ultrotome equipped with glass or diamond knives and the sections were collected on 300 mesh copper grids coated with formvar. Specimens were examined in an AEI 801 electron microscope.

3. Results and discussion

3.1 Stages of decomposition

Needles taken in the uppermost moss layer (*Pleurozium* sp.) in early May, viz. needles under decomposition only during the winter, were heavily attacked by fungi (Fig. 2). The fungi had started invading the cells and the space between them. The cells illustrated belong to the phloem structure located in the middle of the needle (Fig. 1). Since the phloem cells are connected along the whole needle by pores it is possible that they could serve as a route for fungi invading the needle.

The weight loss value can vary between 8 and 17% (for the 5-month period from Nov 1 to May 1) (Berg, to be published). Although the temperatures are low in general, and under the snow cover a few centigrades above zero, the moisture is high enough to support the considerable ingrowth of fungal mycelium that has taken place (from 0 to 2000 mycelium/g needles) (Berg & Söderström, in manuscript).

The needle shown in Fig. 3 had a position in the moss indicating that it might have been in the S-layer for 1-1 1/2 years (Berg 1975). The cells shown might originate from the hypodermis (Fig. 1). It is notable that these cells are much less attacked than the phloem cells in spite of the longer time they have been exposed to decomposing organisms. It thus could be expected that there is an ordered degradation of the needles, viz. that different structural parts are degraded in a certain order.

3.2 Types of organisms observed

The investigation revealed exclusive growth of fungi in the cells (inside the needle) (Figs. 2 and 3) and no bacteria could be seen. Since the needles are comparatively acid - 1 g of finely ground needles of fresh litter in 50 ml of distilled water gave pH 4.7 - fungi could be expected to dominate in the early decomposition processes of the litter.

In slightly later stages of decomposition they apparently are also the only type of microorganism - even after more than one year's decomposition when the needle had lost more than 28% of its weight (Berg 1977). This fact is of importance as it affects the theories for litter decomposition to be used in the building of a mathematical simulation model for soil processes. It appears reasonable that fungi should be the dominating group of microorganisms as they have the property of penetrating the cells (cf. Nilsson 1974; Berg & v. Hofsten 1976).

4. Literature

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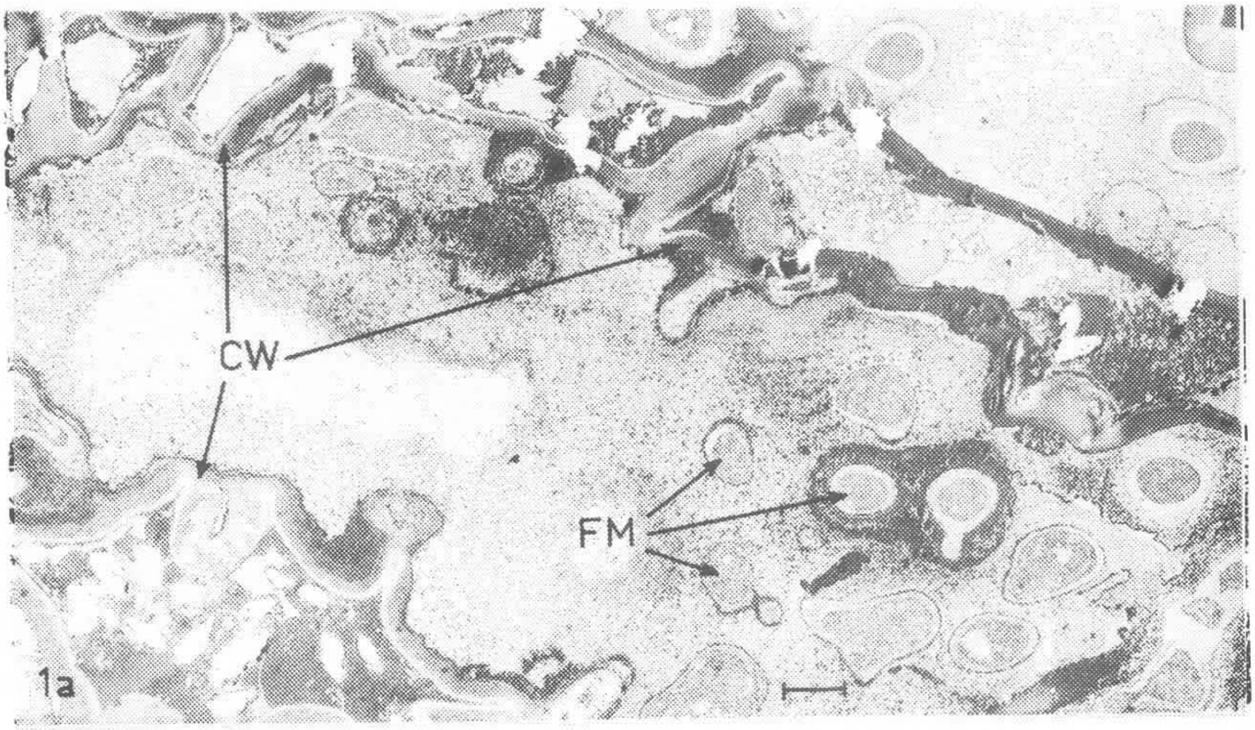

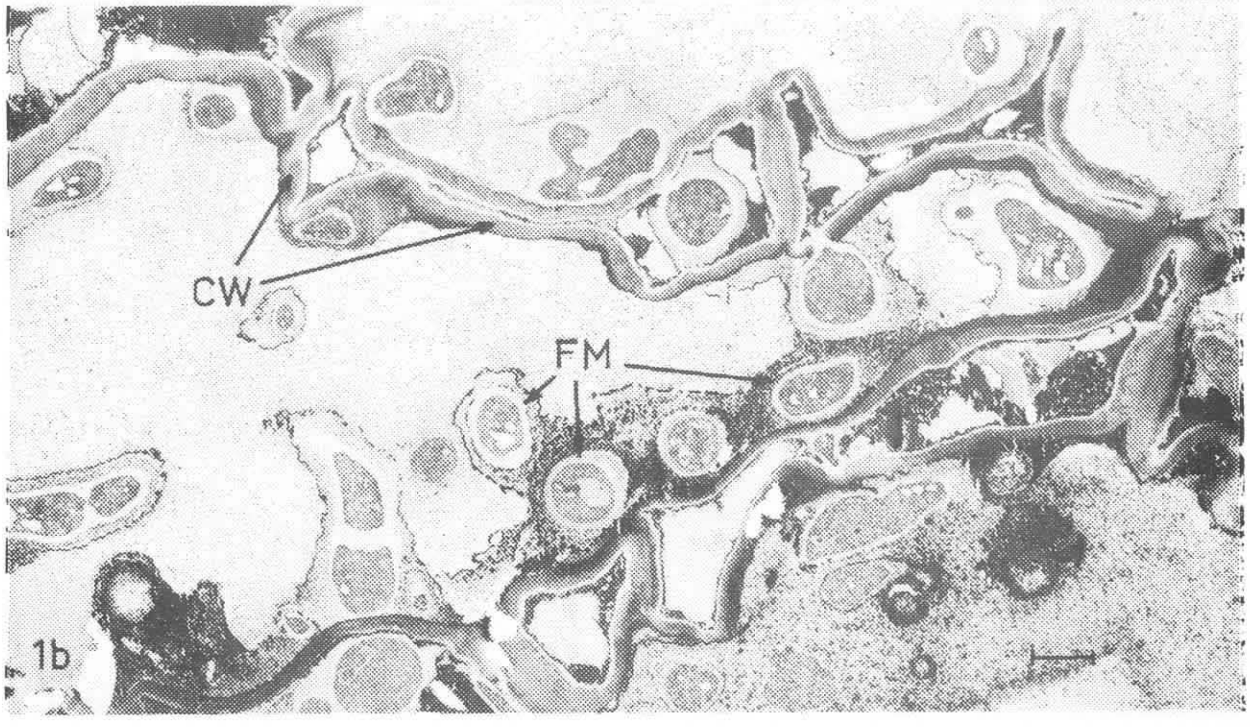

Fig.1. Section of a *Pinus silvestris* needle under decomposition. The electron microscopeic picture shows parts of the phloem structure. CW indicates plant cell walls, and FM fungal mycelium. Bar indicates 1 μm.

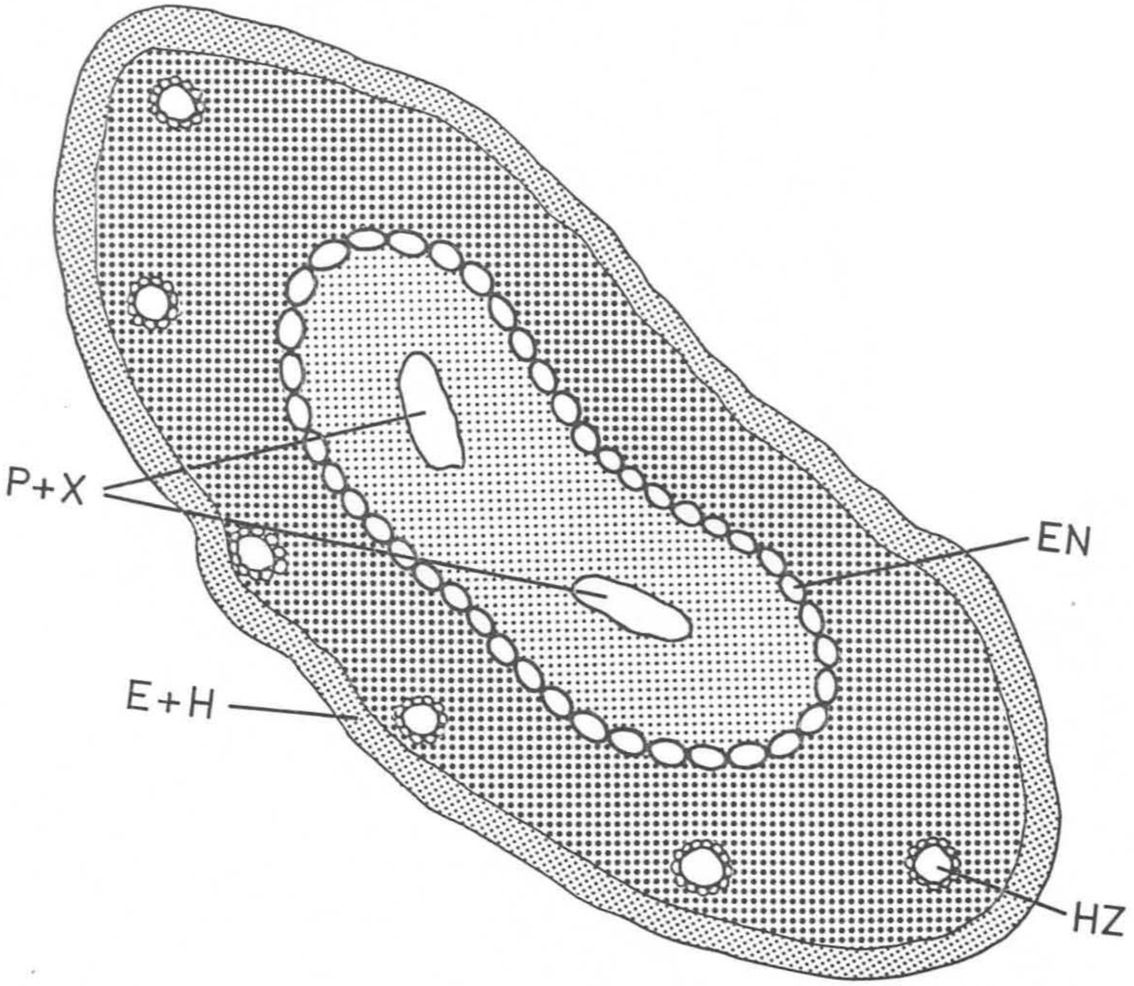

Fig. 2. Schematic drawing of a transection of a Pinus needle. P + X indicates the position of phloem and xylem structure. E + H epidermis and hypodermis, HZ hartz canal, and EN endodermis.

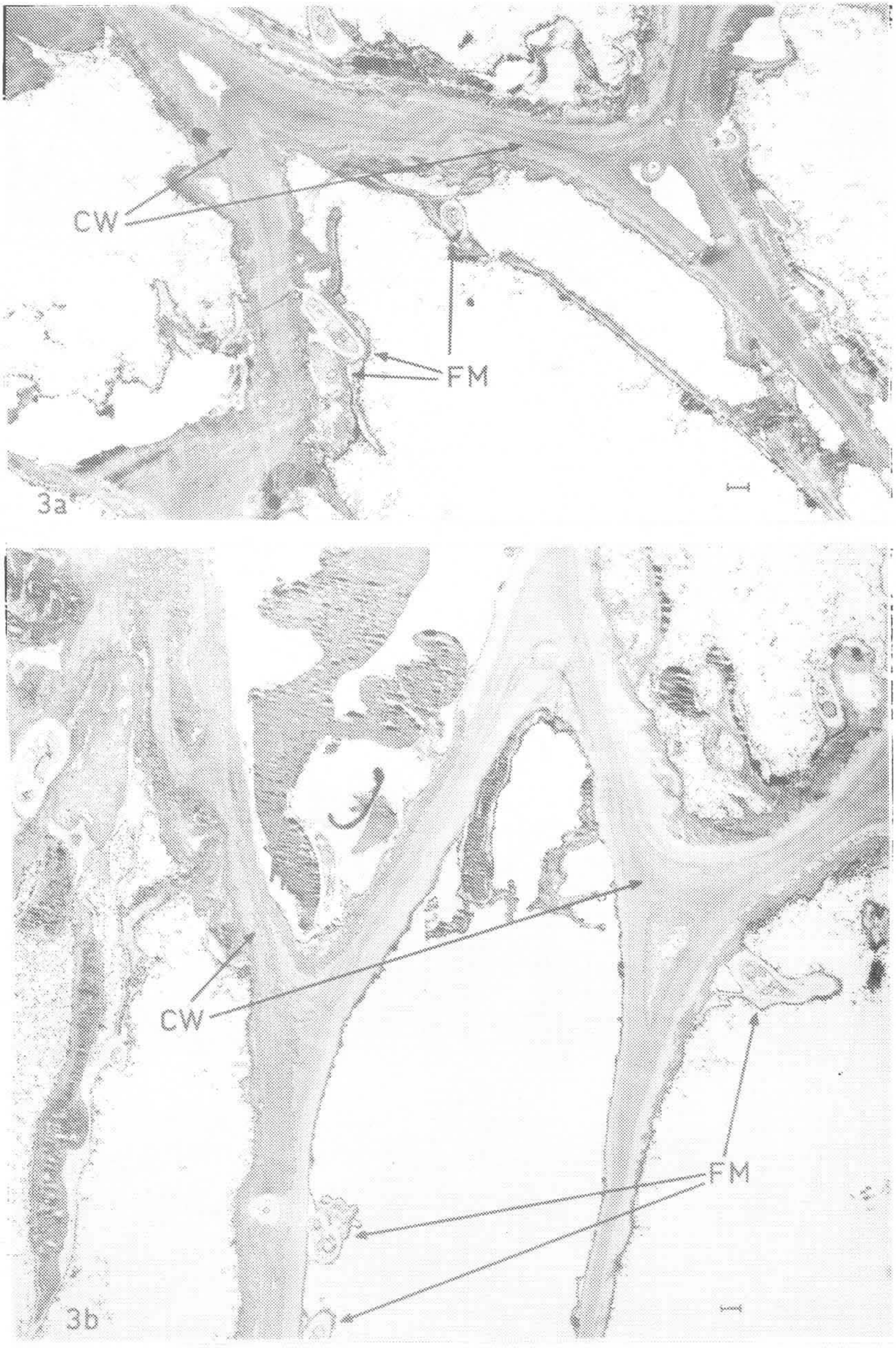

Fig. 3. Electron microscope picture of phloem cells from *Pinus silvestris* needle litter under decomposition. CW indicates plant cell walls and FM fungal mycelium. Bar indicates 1 μm.

4. WIND TRANSPORT OF NEEDLE LITTER IN A CLEAR-CUT AREA

1. Introduction

Litter on the ground is transported in different ways; whole litter pieces can be transported by animals and by wind in horizontal directions and by animals and by moss growth vertically (overgrowth). A study on the overgrowth of needle litter has been undertaken in the 120-year-old forest (Ih V) (Berg, 1977). No transport by wind took place. In such an open area as the vast clear-cur area (Ih I) wind could be expected to influence the positions of litter, e.g. by transporting it from a windy place to a more sheltered area. A limited study was carried out to study whether wind transport might affect the position of litter. If litter is transported away from an area this will affect the amount of nutrients, e.g. nitrogen, which will be released there by decomposition.

2. Material and methods

Needles were marked with a spot of white paint at one end and 250 samples were spread over small areas (30 x 40 cm^2).

The experiment was started on 23 May, 1973 and the first observation was made after a week and the second after a month.

3. Results and discussion

In less than a month all the needles in the two 30 x 40 cm^2 had been transported more than one meter away and only few were to be found within a two meter radius. The study took place when the weather was dry and it is possible that a rainy summer - with heavier litter particles - could have given rise to a slower transport. At the time of the study the shrub was completely dry and the dry moss had mainly disappeared.

As a general observation it was noted that very few needles were to be seen on the ground, whereas litter like small twigs had remained. As the study only had a superficial character it will not be possible to draw many conclusions but I would suggest the following:

1. All loose litter particles of the size of pine needles and smaller are easily transported by the wind on a clear-cut area (where the vegetation is dead and has dried out).

2. As they are easily transported they may be transported away from the clear-cut area.

4. Literature

BERG, B. 1977. Downward transport of needle litter through the moss layer in a 120-year-old pine forest (Ih V) at Ivantjärnsheden. Swedish Coniferous Forest Project. Int. Rep. 63.